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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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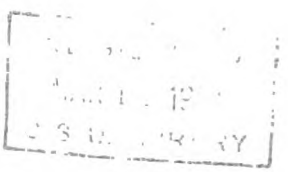
INFORMATION CIRCULAR

MINING METHODS AND COSTS AT THE SPRING HILL MINE, MONTANA MINES CORPORATION, HELENA, MONT.



BY

A. L. PIERCE

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

MINING METHODS AND COSTS AT THE SPRING HILL MINE MONTANA MINES CORPORATION, HELENA, MONT.[1]

By A. L. Pierce[2]

INTRODUCTION

This paper describing the mining practice at the Spring Hill mine of the Montana Mines Corporation, Helena, Mont., is one of a series issued by the Bureau of Mines on mining methods and costs in various districts. Its purpose is to summarize improved methods whereby lower costs have recently been obtained. These improvements are principally the adoption of a modified sublevel stoping method of mining, the use of grizzlies underground, improvements in haulage, and wage bonuses.

The Spring Hill mine is situated in Grizzly Gulch, 3 miles southwest of the city of Helena. Helena is on the lines of the Northern Pacific and the Great Northern Railways; and the East Helena smelter of the American Smelting and Refining Co., to which the concentrates from the mine are shipped, is but 6 miles east of Helena. The mine is producing 150 to 200 tons of gold ore per day, with an underground crew of about 40 men.

The geologic description given in this paper is largely taken from a recent paper on the district by F. C. Schrader.[3] Much of the local history was supplied by A. R. Sherman, the company's assayer. The paper has been approved by Gust Carlson, vice-president and manager of the company.

HISTORY

In 1864 gold was discovered in Last Chance Gulch where the business district of Helena now stands. This gulch, Grizzly Gulch, and other gulches nearby, are locally credited with a production of nearly $40,000,000 in placer gold in the decade that followed. Lode gold was shortly afterward found at the Whitlatch Union mine, three-quarters of a mile from the Spring Hill mine.

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6402."

2 One of the consulting engineers, U. S. Bureau of Mines, and mine superintendent, Spring Hill Mine, Montana Mines Corporation.

3 Schrader, F. C., Metalliferous Deposits in the Winston-Deer Lodge Area South of Helena, Montana: U. S. Geol. Survey, Press Release, August 27, 1929.

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This mine produced $6,000,000 in gold. The Spring Hill mine was discovered at about the same time, and some of the claims were patented in 1869. Little mining seems to have been done, however, until about 1900. At that time a company known as the Butte and Pittsburgh Co. started mining pyrrhotite for flux to be used at the Pittsmont smelter in Butte, where pyritic smelting was practiced. This company did a considerable amount of work in the ensuing five years and opened the mine to a maximum depth of 200 feet by means of an adit connecting with a shaft to the surface. In 1907 other interests purchased the mine, and in that year and the following year there was mined about 22,000 tons of gold ore, which was milled in the Whitlatch mill. This company put down a shaft 100 feet below the other workings and did some drifting at the lower level. In 1927 the Montana-Idaho Mines Corporation, which was later succeeded by the Montana Mines Corporation, acquired a lease and bond on the property. The first work of the new company was to drive an adit, which is now the main haulage level, to connect with the lowest level of the former workings.

GEOLOGY

The ore body is a large, irregular, contact-metamorphic deposit containing gold as the only valuable mineral. The contact is between the carboniferous Madison limestone and an intrusive body of fine-grained diorite. This diorite is a basic segregation of the quartz monzonite of the Boulder batholith, or the so-called "Butte granite," which is the dominant rock of the region. The lime has been marbleized and all evidence of bedding destroyed for over 100 feet from the contact.

The massive pyrrhotite, for which the mine was originally opened, occurs next to the marbleized lime in widths varying from 1 or 2 feet to more than 30 feet; it sometimes forms pockets in the lime. Between the pyrrhotite and the diorite is found the main body of ore. This ore, known locally as pyroxenite, consists of pyrrhotite, pyrite, marcasite, and arsenopyrite associated with a fine-grained aggregate of lime-silicate minerals, chiefly tremolite and diopside. Ankerite is found in fairly large quantities in some portions of the deposit.

The average grade of the ore is about $6 per ton in gold, although the value is not consistent. The gold occurs native and in combination with arsenopyrite and pyrite. Bismuth and antimony are present in small quantities and appear to carry some gold in combination. Minerals containing these elements have not yet been found, and their presence is known only by means of assays of the concentrates. The pyrrhotite itself seems to be barren of gold, but it usually has inclusions of gold-bearing arsenopyrite and pyrite.

Physical Characteristics

The ore is extremely hard and tough. It will stand in almost any form over spans of 60 feet or more, although it is cracked and seamed in many directions. The dominant cracks are due to jointing. They dip about 35° to the northeast and strike nearly at right angles to the strike of the ore. At intervals of from 6 to 30 feet vertically there has been movement along the plane of the joints. These slips are characterized by a calcite filling and are responsible for movements of the walls for distances as great as 15 feet. A gouge

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seam is found at the border of the ore at the limestone, and very often another is found on the diorite side. In addition, a number of seams cut the ore diagonally and have a very high angle of dip. These seams and cracks tend to key themselves so that it is often difficult to bar loose pieces down. In conjunction with the hard and tough ore, these numerous cracks give rise to large rough pieces when the ore is blasted. It is common to find bowlders with drill holes through them after blasting.

The ore, like most contact-metamorphic deposits, is quite irregular in outline. In most places the dip is nearly vertical, although locally it may flatten out as low as 60°.

The marbleized limestone wall is very irregular, but it has few seams and stands well. The diorite is jointed even more extensively than the ore, but as it is also quite strong and is required to stand only in nearly vertical faces, it gives no trouble.

EXPLORATION

Prospecting and exploration are carried on by a combination of drifting, crosscutting, raising, and dizmond drilling. Where it is possible to get crosscut holes to the contact, diamond drilling is used; otherwise drifting is resorted to. Long-hole drills have been used but have not been very successful because in the hard rock the steel loses gauge so rapidly that it is almost impossible to get a hole deeper than about 35 feet. Diamond drilling is done by the company at a cost of $3 per foot.

SAMPLING AND ESTIMATING RESERVES

In drifting, crosscutting, or raising, a sample is taken of each heading, usually from drill cuttings, in addition to a grab sample from the broken material of each round. All assay records are filed.

Hand samples of faces are not reliable because of the extremely spotty nature of mineralization. Grab samples of the broken ore, which is very coarse, are not to be entirely relied upon. The appearance of the rock has considerable weight in distinguishing between ore and waste. Grab samples are taken from all cars loaded from a given chute in a 24-hour period. These samples are not accurate, but they are indicative of the ore being mined into that chute. The mill heads sample is the most accurate one obtained and forms a basis for checking the appearance and assay value of ore taken from the chutes.

Estimates of tonnage taken from the mine are based on a factor of 1.8 tons per car. These are checked accurately in the mill by weighed samples. Estimates of ore reserves are made by roughly measuring blocks of approximately uniform value and figuring tonnage on a factor of 10 cubic feet in place per ton of ore. The value of a block is arrived at by observation of the ore and from experience based on chute samples, hand samples, drill cuttings, and mill heads. It is wasted effort to try to measure reserves more accurately as the ore is about three-fourths mined out before the outlines are fully known, and it is entirely mined out before the correct value is known; this is because of the irregular ore outline and the spotty distribution of the gold.

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DEVELOPMENT

The mine is developed from an adit, the lowest of the old workings. This is the only haulage level, and cars are trammed directly from the chutes to the crushing-plant ore bin, 500 feet outside the portal of the tunnel. All of the ore mined up to this time has come from above this level, and is led into the chutes by gravity. The haulage level follows the contact. Figures 1, 2, and 3 illustrate the plan of development of the mine.

No. 1 shaft, or the old shaft, is used for handling drill steel and supplies to the open-cut and the stope in the west ore body. A newly completed timbered raise on the east ore body gives passage for men and supplies to that section of the mine. This last raise also served to show the width of the east ore body between the 200 and 300 levels.

At present the eastern ore zone is being explored by means of raises, which will be used later as part of a sublevel stoping system if the ore proves to be wide enough. No shaft sinking has been done as yet, although a shaft is planned for the near future.

Development Details

Tunnels, drifts, and crosscuts are 7 by 7 feet in cross section and are driven on a 0.5 per cent grade, with a water ditch below the track on the left side. It is seldom necessary to support drifts, but where timber is required standard drift sets of round timber and pole lagging are used. The rounds are drilled with either upward-cut or downward-cut holes depending upon the jointing, as shown in Figure 4. It has been found that the best results are obtained by having the cut-holes cross the jointing. Drilling is done with a heavy Leyner-type machine mounted on a column and arm. Drilling is done on the night shift in order to balance the air consumption with the air used in the blacksmith shop on the day shift. A drift crew consists of four men, two men drilling the round on the night shift and two men shoveling on the day shift. Shifts change every two weeks, so that all men share alike under the bonus system in use. The average round pulls 5-1/2 to 6 feet and requires about one 50-pound box of 40 per cent strength gelatin dynamite. Six-foot fuse is used for drift and raise rounds.

Raises that are to be used as ore passes are 6 by 8 feet in cross section and run on an inclination of about 60°. The only timbers used are sprags from which to drill. Raises that are to be used as manways and for supplies are put up vertically with a cross section of 6 by 9 feet. These raises are stulled and lagged to form a manway on one side. The bulkhead used when blasting is shown in Figure 5. In medium ground the round is cut to one side or the other so as to cross the jointing. In exceptionally hard ground, V-cuts in the center are used.

Self-rotating wet stoper drills are employed. Two men with two machines drill and blast a round a shift in inclined raises and a round every other shift in vertical timbered raises.

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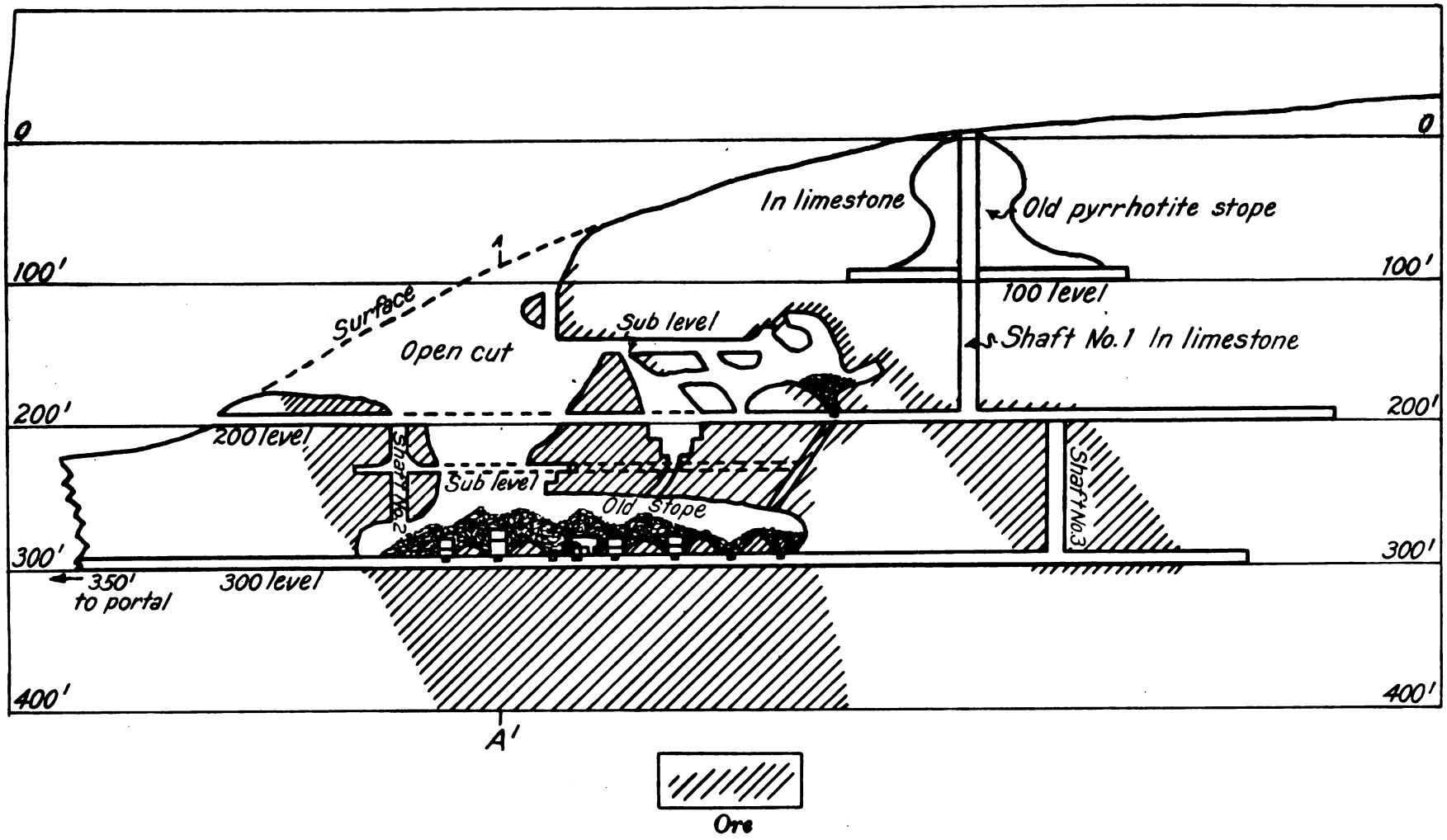

Figure 1. — Longitudinal section. Only ore proved by workings and drilling is shown

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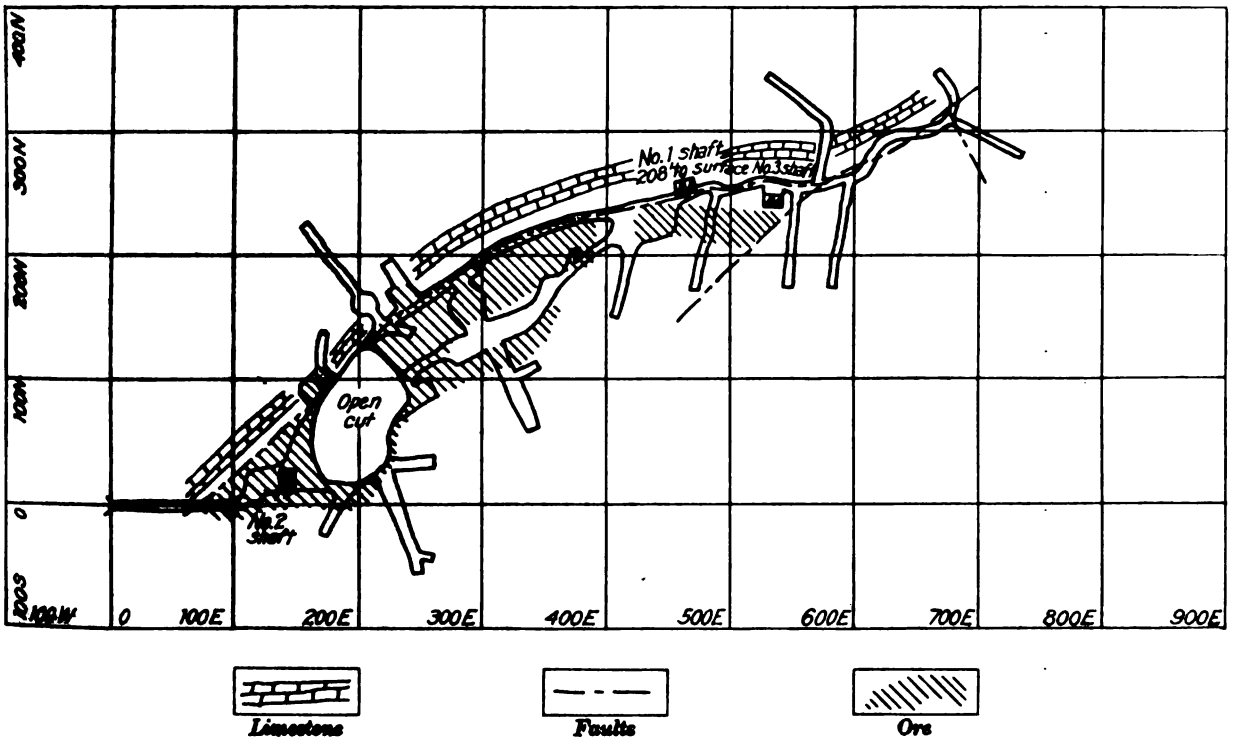
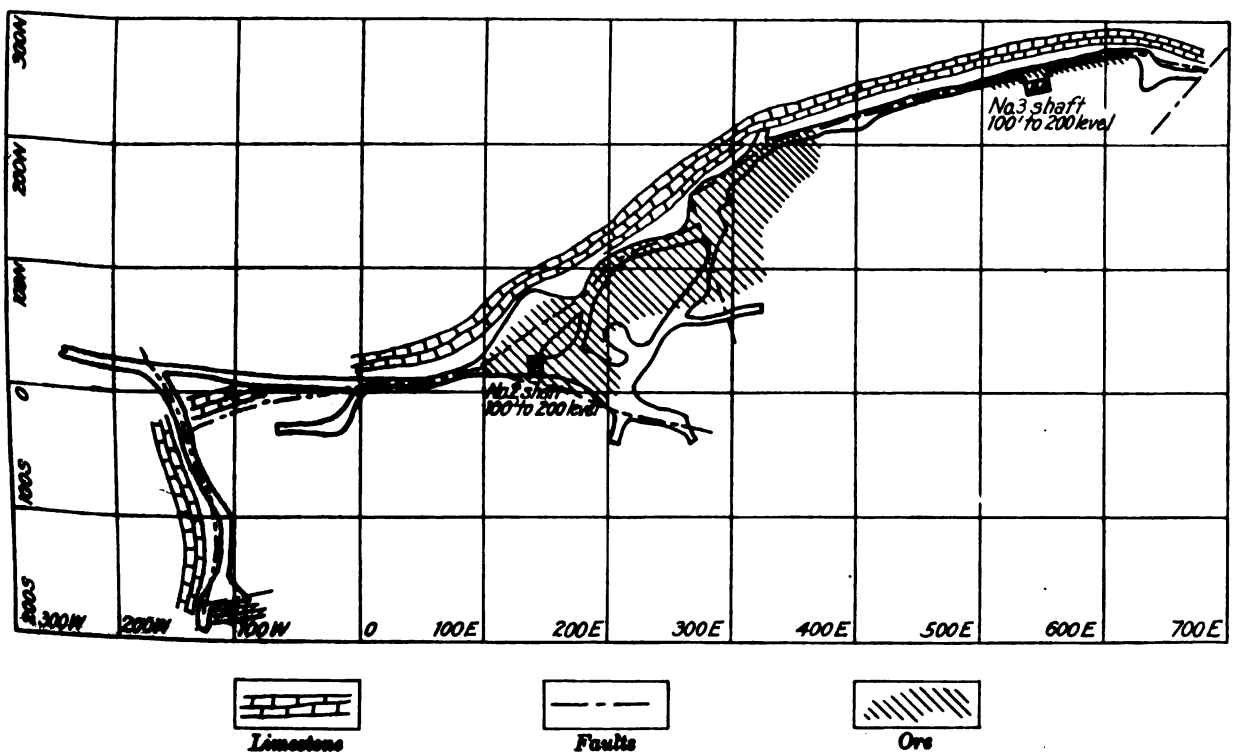


Figure 2. — Plan of 200 level



NOTE: Stops above level taken for outline of ore

Figure 3. — Plan of 300 level

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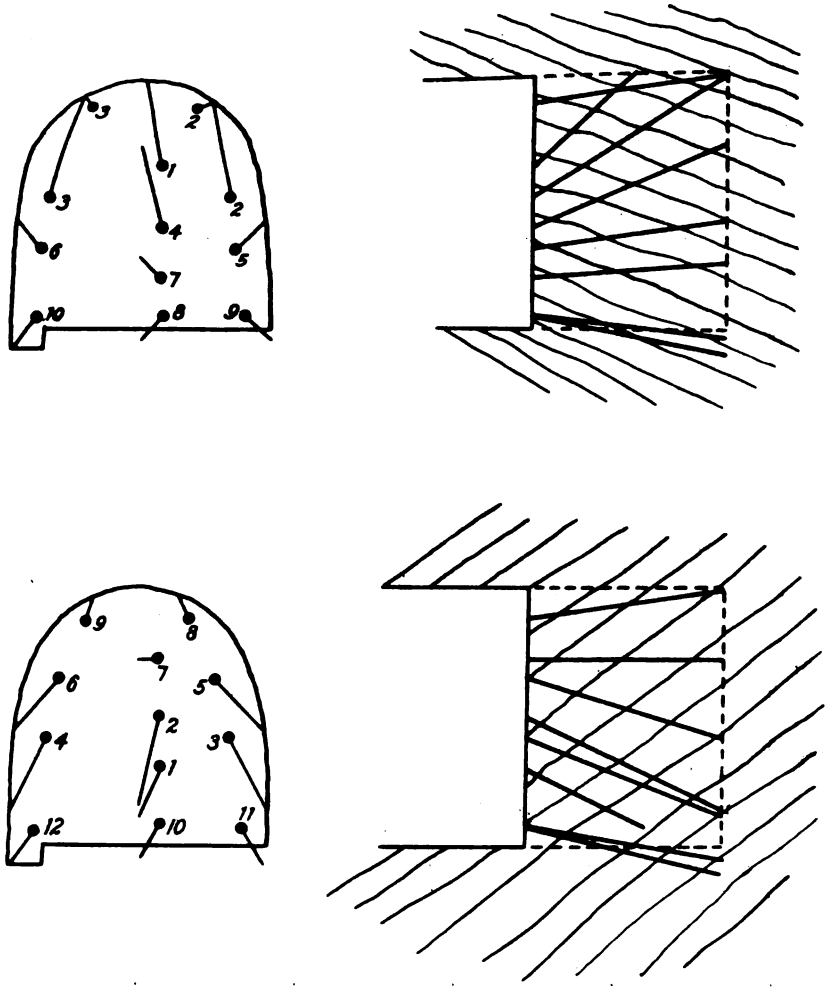

Figure 4. — Drift rounds, designed for cut holes to cross jointing. Numbered in order of firing

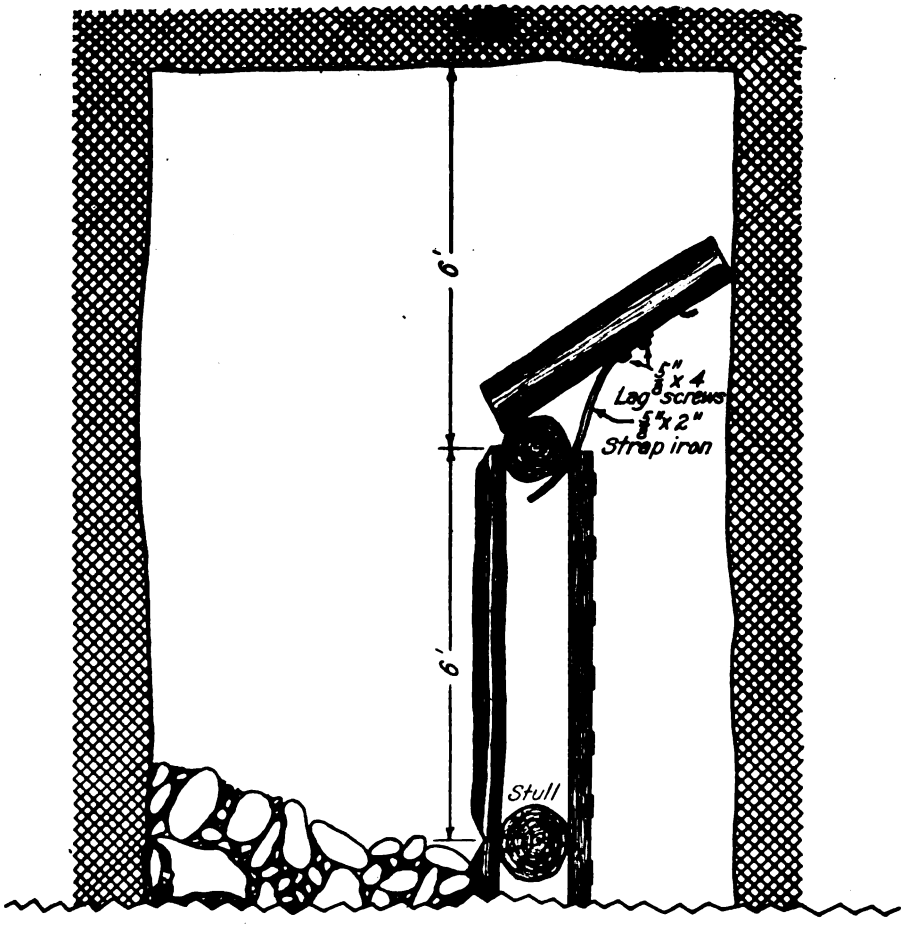

Figure 5. — Timbered raise at time of blasting

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About one 50-pound box of 40 per cent strength gelatin dynamite is sufficient to pull a round of 5 to 5-1/2 feet. Two men are usually given a raise on a footage bonus system.

Drifter drills use 1-1/4 inch hollow round drill steel, stoper drills 1-inch hollow quarter octagon steel, and jackhammer drills 1-inch hollow hexagon steel. An 18-inch change in length of steels and 1/8-inch change in gage of bits is standard for all drill steel. Starter steels are 2 feet long. Leyner steel bits start with 2-1/4 inch gage and all others start with 2-inch gage. Blockholing steel is made up of short broken pieces of jackhammer steel with a bit just large enough to clear the cuttings. A 750-cubic feet per minute angle-compound air compressor supplies the air for drilling.

MINING

Under the old system of mining, a shrinkage stope was started above the adit level by putting in chutes at 40-foot intervals with 45° connecting raises. The ore between and above these raises was mined out and the opening widened to both walls. Stoping was then started. It soon became apparent that the ore body was much wider than expected, which gave rise to unexpected difficulties. Moreover, the chutes were spaced too far apart for good control of the level of broken ore in the stope. Because of the width of the stope and the physical characteristics of the ore, as previously explained, shrinking was dangerous, as large slabs would become loosened and were difficult to bar down. Blockholing was expensive because the bowlders had to be dug out of the ore. Some bowlders would be buried and missed, causing a tie-up in tramming when they got into the chutes. The investment in broken ore was also excessive.

It was then decided to try a modified system of sublevel stoping similar to that in use at the mines of the Tennessee Copper Co. at Ducktown, Tenn.[4] In adapting this system to local conditions it was decided to use as many of the old workings as possible and to make a test of the method. One of the shrinkage chutes was pulled empty, and a grizzly chamber built of timber was put in above the chute. Then by using a small intermediate level, which was about halfway vertically between the back of the stope and the 200 level, and a raise from the stope to the intermediate level, slabbing and benching were started over the grizzly (see figs. 1 and 6). This method worked so well that the broken ore in the rest of the stope was drawn down, ore missed in going up was benched off, and timbered grizzlies were built or are in process of building in each of the old pull holes. The ore between the intermediate and the 200 levels, which formed the bottom of the old opencut, is being taken out by coming up with stoper drills from the intermediate level. Not all of this ground is drilled and blasted, as it is found possible to weaken it on the diorite side so that a final round of holes will break through and allow it to cave to the limestone on the other side. This change in method has taken some months and is not yet completed. The mill has been supplied almost entirely with the ore derived from this work. The costs of mining given in the tables at the end of this paper cover this period of the transition.

4 - McNaughton, C. H., Mining Methods of the Tennessee Copper Co., Ducktown, Tenn.: Bureau of Mines Information Circular 6149, 1929, 17 pp.

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Slabbing is done with Leyner-type machines or with mounted jackhammers with column and arm mounting. Benching is done with heavy jackhammers. The benching is planned to retreat from east to west where possible so as to take advantage of jointing for overbreaking. Bench holes are drilled 6 feet deep, 4 to 5 feet apart, and given a burden of about 4 feet. Slabbing holes are drilled three in a row to a depth of 7 feet and given a burden of about 4 feet. It can be seen that an effort is made to break as much ground as possible with the primary holes. This is because secondary blasting is about the same regardless of how closely the primary holes may be spaced. The miners are furnished with sharp steel, powder, and primers by the nipper. They blast their own holes.

Practically no timber is used in the mine except on the haulage level and for the grizzly chambers.

No standard type of grizzly chamber has been evolved. In each case the chamber has been made to fit the ground as found in the old pull holes and with a minimum of blasting. The grizzly itself is made of 90-pound rails with the web up and spaced 12-inches apart. The rails soon wear so as to give an opening of about 14 inches. Timbered grizzly chambers are costly both to install and to maintain, and the new sublevel stopes will have the chambers blasted out of solid rock. An effort is made to blast as many bowlders in the stope above the grizzlies as is consistent with safety. Bowlders blocking the brizzly pull holes are drilled with hand-rotated stoper drills, and the bowlders too large to pass the grizzly bars are either broken with a 14-pound hammer or blockholed with a jackhammer. A stoper and a jackhammer are standard equipment for each grizzly.

Where the ore body is narrow, as in the east end of the 300 level, a shrinkage system is used. This is started by laying plank for shoveling plats and then stoping the back of the drift to a height of about 14 feet. The resulting broken ore is shoveled by hand. Stulls are placed 7 feet above the track on 6-foot centers and lagged with pole lagging. Chutes are installed at intervals of 18 feet. The first cut above the timbers is blasted lightly to save the timbers, but as soon as they are protected with ore, the stope is carried up in the usual manner.

UNDERGROUND HAULAGE

The loading chutes are built of 10 by 10 inch posts and 3-inch plank. Chute doors are of 4-inch round fir. This type of chute door lasts a long time, is easily handled, and a spare is quickly put in place if the regular door is lost in pulling the chute. The ore fragments are so large and blocky that no type of mechanical chute door has been considered practicable. The bottoms of the chutes are cribbed and filled with ore, on which the bottom planks are placed. The bottom planks are protected on top with a steel sheet. This construction is found to make a fairly fast-loading chute and one that will stand considerable blasting.

Hand-tramming is almost entirely eliminated. Tramming on the haulage level is still done with the aid of horses, but the length of the haul is relatively short. The ore cars are of a plain-bearing side-dump type which are purchased from a large copper-mining company. It has been necessary to reinforce

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the cars rigidly in our own shop. They are of 35 cubic foot capacity, and weigh 1 ton empty and 2.8 tons under the average load. The usual train consists of 6 cars coupled by means of chains and hooks.

The track is of 18-pound rail over most of the haulage level, but all new tracks and replacement tracks are being laid with 24-pound rail; the gage is 18-inches. All track on the haulage level has been straightened, long-radius curves substituted for short, and the entire track has been brought to a uniform grade. Throw switches made in the blacksmith shop during spare time have replaced the old type single-point switches. The improvements in the track have eliminated many derailments, and have made it possible to tram more ore than formerly, and at a reduced cost.

ORE EXTRACTION

It is estimated that more than 90 per cent of the ore above the haulage level will be extracted by the present method of mining. As the walls are nearly vertical and are self-supporting, pillars are not required and will not be until lower levels are opened. There is practically no dilution of ore by the limestone, as this stands well, is easily detected when drilling, and is therefore seldom blasted. Some dilution by diorite is unavoidable as in places there is a slip on the diorite side that compels the taking of low-grade material. At other points the ore gradually grades into diorite, and stoping limits must be set by assay values. In an irregular ore body this condition means that some low-grade material will be blasted. No attempt at sorting of ore is made because of the difficulty of readily distinguishing between ore and waste. The waste from exploration and development is trammed to the waste dump on the surface.

COMPARISON OF DIFFERENT METHODS

In a wide ore body, sublevel stoping has the following advantages over shrinkage stoping: (1) Sublevel stoping is safer because men are working under a freshly broken and barred back which is readily accessible during the short time it serves for protection; the men are not exposed to the danger of being drawn down with the ore if the trammers below pull the wrong chute or if the ore hangs up and suddenly drops; (2) more ore is recovered, as irregularities are found and followed more easily; (3) the cost of mining is lower because bowlders do not have to be dug out of the ore to be blockholed, and none escape the grizzly to slow up the tramming; (4) it eliminates the investment in broken ore, which becomes excessive with a large ore body, and (5) tramming from any given pull hole does not have to stop because men are working above it.

Shrinkage stoping is suitable in narrow ore bodies at this property because: (1) The ore is found at the contact where there is a contact fault which results in several feet of the ore being soft and friable; in widths under 10 feet the ore breaks much finer than in wide bodies, thus removing many of the objections to this method; (2) men in the district are more familiar with the shrinkage method and are therefore more satisfied and efficient; (3) less preliminary work is required and consequently less expenditure, which tends to offset the investment in broken rock, especially as the tonnage in a narrow ore body is not great.

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WAGES, CONTRACTS, AND BONUS SYSTEM

Mining at the present time is done on day's pay, the rates (August, 1930) being $5 for muckers, trammers, and grizzly men, and $5.50 for miners and car loaders. In the shrinkage-stoping period and during the transition to the new system, considerable chute blasting was necessary. Men experienced in the use of powder were therefore employed as car loaders, and paid the same rate as miners. The length of shift is eight hours. Much of the work will be put on a bonus system as soon as the transition in mining system is complete. Development work is paid for at the rate of $6 per foot for untimbered drifts, raises, and crosscuts, and $7 per foot for timbered raises. Heretofore the company has furnished all supplies, including powder, but this has not been entirely satisfactory, chiefly because more powder has been used than necessary. Future development work is to be paid for at higher rates, with the men furnishing the powder.

VENTILATION

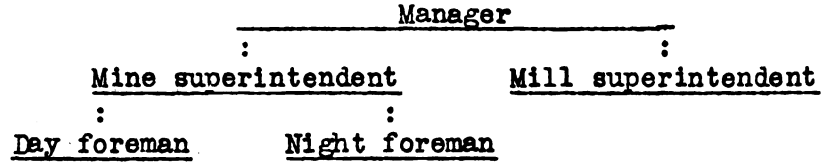
Ventilation is natural, and the air current is very strong. During the winter months it is even necessary to use a door at the haulage portal in order to reduce the draft. The door moves vertically in guides and is counterbalanced so that very little effort is required to move it.

FIRE HAZARDS

With practically no timber in the mine, and a low sulphur content in most of the ore, the fire hazard underground is practically negligible. Most of the outside mine buildings, such as the snowshed and the timbershed, are of sheet-iron construction, and therefore they contribute little to the fire risk. Extinguishers are placed at readily accessible points in the buildings.

ORGANIZATION

The organization for mine operation is very simple, and may be diagrammed as follows:



The manager has complete charge of all work at the property and of the general administration of the company. The mine foreman on the day shift and the mine foreman on the night shift work under the immediate supervision of the mine superintendent. They carry out his mining orders and make contact with the men. Each mine foreman supervises about 17 men. The mine superintendent also supervises the blacksmith shop and the compressor house, and does the engineering as well. His responsibility extends to the ore bin of the crushing plant, and the mill superintendent is in charge of the crushing and the milling.

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MINING COSTS

August 1, 1929 to April 30, 1930. Tons ore trammed: 43,323.

Table 1. - Underground costs per tons of ore trammed

	Labor[1]	Supervision	Compressed air, drills and steel[2]	Power	Explosives	Timber	Other supplies	Total
Development.....	$0.219	- - -	$0.059	- - -	$0.089	- - -	$0.010	[3]$0.377
Mining	.464	- - -	.084	- - -	.121	- - -	.018	.687
Blocking	.274	- - -	.040	- - -	.057	- - -	.014	.385
Transportation (underground) .	.110	- - -	- - -	- - -	- - -	- - -	.021	.131
General underground expense	.109	$0.092	- - -	$0.003	- - -	$0.010	.004	.218
Surface expense (directly applicable to underground operation)	.137	.010	- - -	- - -	- - -	- - -	- - -	.147
Total	$1.313	$0.102	$0.183	$0.003	$0.267	$0.010	$0.067	$1.945

1 - Underground labor costs include surface labor employed in steel shop and compressor room.

2 - Includes power for air compression and materials for drill repairs, air, and water lines. Labor used in repairing drills and laying air and water lines is included under "Labor."

3 - Development cost is lower than normal, as development work did not quite keep pace with ore extraction. Due to mining under the old opencut by methods involving the caving of large amounts of ore, however, reserves of broken ore were increased so that the total mining and development cost is close to normal.

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Table 2. - Summary of costs per ton in units of labor, power, and supplies

August 1, 1929 to April 30, 1930 — Tons ore trammed: 43,323

Method used: Modified sublevel stoping

	Development	Stoping	Total
Labor (man-hours per ton):			
Drilling and blasting	0.145	0.675	0.820
Blockholing	- - -	.406	.406
Shoveling	.105	- - -	.105
Transportation	- - -	- - -	.163
General	- - -	- - -	.174
Supervision	- - -	- - -	.045
Surface labor applicable to underground	- - -	- - -	.191
Total man-hours per ton	0.250	1.081	1.904
Tons per man-shift	- - -	7.40	4.20
Labor per cent of total cost	- - -	- - -	72.70
Power and supplies:			
Explosives (pounds 40 per cent strength gelatin dynamite per ton)	- - -	- - -	1.262
Mining	0.387	0.626	- - -
Blockholing	- - -	.249	- - -
Timber (board feet per ton)	- - -	- - -	.385
Total power (kw. h. per ton)	- - -	- - -	10.43
Other supplies in percentage of total supplies and power	- - -	- - -	12.6
Supplies and power, percentage of total cost	- - -	- - -	27.3
Percentage of total cost	19.4	80.6	100.0

Note: Figures for development are based on total mine production and not on ore from development only.
Drilling and blasting, and blockholing, include labor employed in steel shop.

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Table 3. - Detail of development costs in units of labor, power, and supplies

August 1, 1929 to April 30, 1930

	Drifting	Raising	Raising
Size of excavation	7 by 7 feet	6 by 8 feet	6 by 9 feet
Timbered or not	No	No	Yes
Physical properties of rock	Very hard and tough. Breaks well when properly drilled		
Labor (man-hours per foot):			
Breaking (drilling and blasting)	3.03	6.83	5.21
Shoveling and hand-tramming	3.03	---	---
Timbering	---	---	3.14
Total labor (man-hours per foot)	6.06	6.83	8.35
Feet per 8-hour shift	1.32	1.17	.96
Power and supplies (per foot):			
Explosives (pounds per foot)	9.4	10.2	12.0
Timber (board feet per foot)	---	---	19.2
Power (kw. h. per foot)	46	43	44
Labor (percentage of total cost)	66.9	65.6	63.7
Power and supplies (percentage of total cost)	33.1	34.4	36.3

Note: Labor for sharpening steel and nipping is included in figure for power and supplies. Labor for advancing air and water lines is included in "Labor".

Tramming drift muck and loading and tramming raise muck are not included in development figures.

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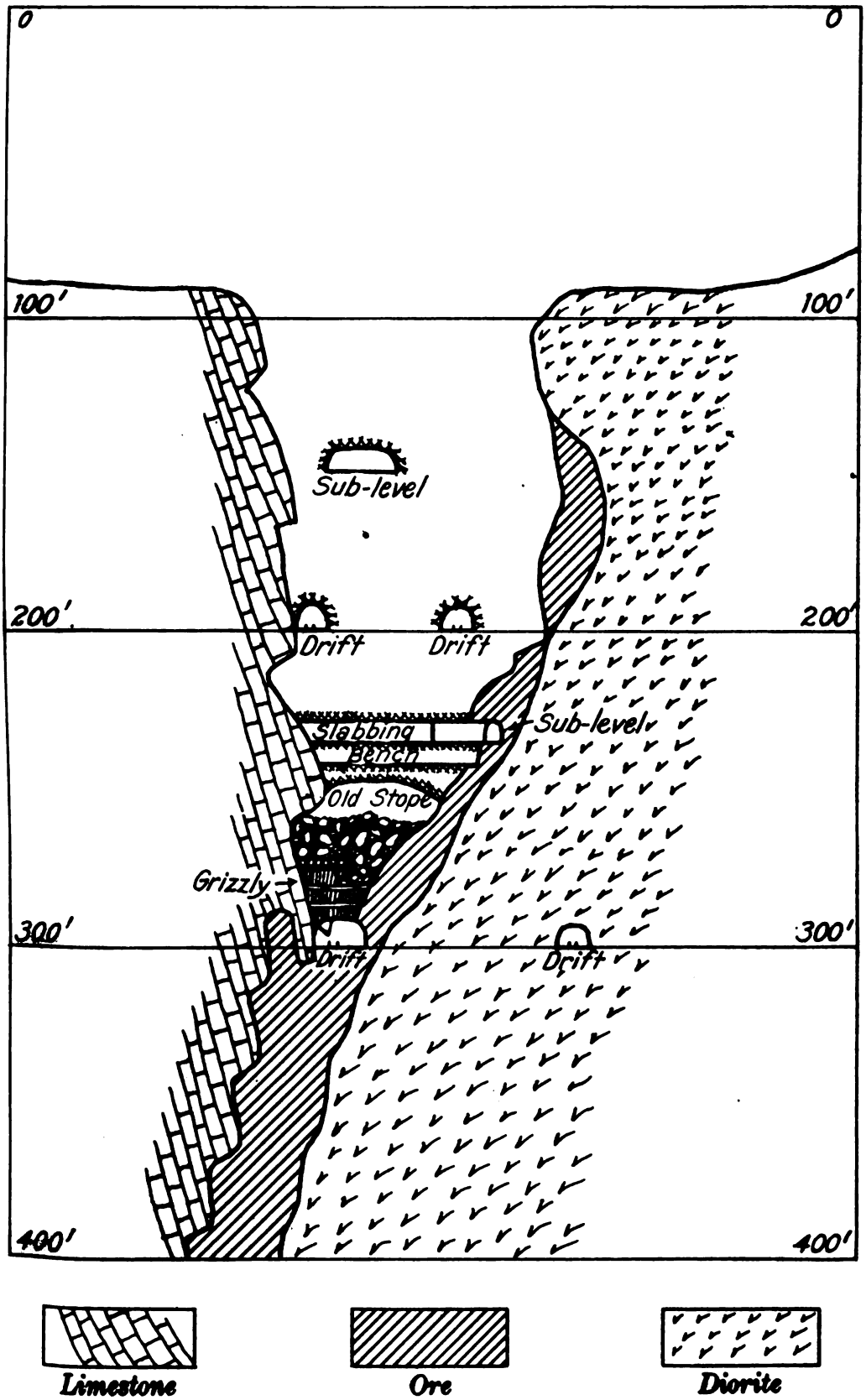

Figure 6. — Cross section at A—A', Figure 1

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